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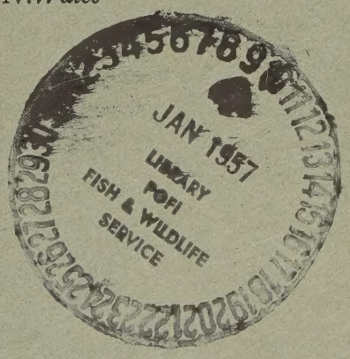
The Great Spatfall of Mussels (Mytilus edulis L.) in the River Conway Estuary in Spring 1940

R. E. SAVAGE, O.B.E.

Formerly at
Fisheries Experiment Station, Conway, N.Wales



LONDON: HER MAJESTY'S STATIONERY OFFICE

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General view of mussel beds on the north bank of the River Conway Estuary looking east: taken

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The Great Spatfall of Mussels (*Mytilus edulis L.*) in the River Conway Estuary in Spring 1940

I. NARRATIVE

e Conway mussel fishery was flourishing in the years just before the war, the output ussels having steadily increased from 539 tons in the season 1930-31 to a record figure 31 tons in the season 1939-40. The latter figure was achieved in spite of an interruption ver 4 weeks caused by the very severe frosty spell in January and February, 1940, of military regulations which prohibited vessels from passing under the bridges during hours of darkness, which they had to do to land the mussels at the Ministry's fication Tanks.

Each year since 1933 the stock of marketable mussels had been maintained by relaying l mussels from overcrowded or otherwise unsuitable areas on to beds depleted by ng, where growth would be quicker.

Towards the end of this 1939-40 record season, however, a spatfall of phenomenal portions took place, and by the end of April, 1940, the whole estuary was covered by ig mussels of about 2 mm. in length. The spat was first noticed during April attached ussels brought to the Conway Purification Tanks for cleansing prior to despatch to et.

A survey was made on the next spring tide—6th May—along with Conway Corporation als and mussel fishermen. The whole of the area below high-water mark in the lower ary was found to be covered with a dark brownish-black carpet of young mussels. spat had settled not only on all the mussels on the beds, and on stones, sea-weed, etc., all over what had been bare sands as well, where clusters of young mussels were rved clinging round the mouths of worm tubes.

The oldest fisherman had never seen such a massive spatfall. He remembered that about ars before there had been a very heavy and unusual fall of spat, following which they unable to gather mussels for marketing for several years*, but said that the present all was a very much bigger one and he feared that the old mussels would not survive it. laboratory records show that there was another heavy spatfall in 1922, but it was patchy of limited extent. It was soon thinned out by gales, and mussel fishing was not rupted.

The minute post-larval mussels may be swept along by current and tides (Baggerman,), and may be carried to unsuitable places, e.g., on bare sand, or left high and dry at -water mark, and so perish. Those on the sands were attached to each other in clusters to a thousand or more individuals, the whole masses precariously attached to small les, etc., and, it almost seemed, to grains of sand (Fig. 1). If a cluster was disturbed ily became detached and floated away. In rough weather these would soon be dispersed only those with a firm anchorage would survive. During the Spring and Summer of there was a comparative absence of gales and so the young mussels remained on and id the mussel beds and even on the sands.

s the young mussels grew in size they gradually smothered their parents, and the latter, ved of food by the myriads of their competitors, and no doubt weakened by the me frost and subsequent spawning, lost condition and died.Over 700 young mussels

e not been able to fix the date of this spatfall (of about 40 years before 1940), but the extreme frost of ry and February 1895, referred to below (p. 19), was 45 years before, and it is conceivable that the awning was in that year.

were counted attached to each of several large mussels—about 2½ inches in length—tak at random (see Fig. 2). And so the immediate result of this wonderful abundance of s was disaster to what had been a well-stocked fishery. The disaster was not so serious a would have been had it occurred in peace time, as the younger musselmen had joined fighting services, while most of the older men were profitably engaged in inshore fishing other employment.

The first changes to be noted took place on the sand banks, particularly on the no side of the estuary where the young mussels had only the flimsiest anchorage. Bare patc soon appeared and increased in number and extent each month until with the Autumn a Winter gales the higher parts of the sand banks were almost cleared of young muss On and around the established mussel beds, where there was firm anchorage, the chan were slower and much smaller in extent. Small bare patches did occur here and there a result of scouring, but, at first, the patches tended to become re-populated.Some very sn bare patches were noticed in late May on unsuitable ground, but were covered again June. Similarly in July, particularly on the Morfa banks, the mussels appeared to be e more widespread than in June, and spat had extended farther upstream towards Degan where before there were but few. It was also noticed that spat had been dislodged from upper surfaces of some stones and large mussels which later became covered ag At high-water mark there was a thin line of stranded young mussels, and after the g had arrived later in the year, this line had become a considerable band, especially along eastern shore where the river makes a sharp bend. Among the stranded young mussels w some still attached to the mouths of worm tubes which had been uprooted and car away.

There were still enormous quantities of young mussels on the beds, and as they g in size, more and more mud settled below them, and, when scouring took place in ro weather, patches of mud up to several square yards in extent would be carried away w the mussels above it. The amount of mud present varied in different parts of the ba In some regions, notably near the Perch Beacon (Fig. 3), and along the bank between th and 'The Beacons' (not a light, but named after a nearby house, since demolished), th was very little, which usually indicated a shifting population. Near the Perch Beacon was very marked, a patch would be clear of mussels one month, and covered, or pa covered, the following month. In such cases there was often evidence of mussels be sanded over.

As time went on the depth of the slimy black mud under the mussels was such tha became difficult to walk over (or rather through) the beds during surveys as one sa foot or more into the mud.

By the end of 1942 the area covered with mussels was not much greater than tha normal years. Its approximate extent is shown as stippled areas on the maps in Fig There were still enormous quantities of mussels, especially on the banks on the Morfa s of the estuary, and the outlook for a rich harvest when they reached marketable size, fishing could be resumed, seemed promising.

The position in the channels was, however, somewhat disappointing, as we had many blank hauls in places where musselmen were accustomed to rake successfu There was some hope that these areas might be re-populated as there was constant evide of movements of mussels. Doubtless when scouring occurred on the banks some of mussels washed away would be carried into the channel and settle there. The bank in channel, known as Green Island (Fig. 3), which is only exposed for a short time at water of good spring tides, had a very fluctuating population. The bank itself is rat unstable, and so it was found that at first there was only a moderate settlement of spat, later it became densely covered, and the mussels there grew more quickly than on o banks. Later it was almost completely depopulated, only to recover again.

A short account of the 1940 spatfall is given in the Ministry's report 'Fisheries in W Time' (1946, p. 56).

Fig. 1. *Close-up of 3 months' old mussels settled on sand bank in clusters. (Round disc is* $\frac{1}{2}$*d. = 1 inch diam.).*

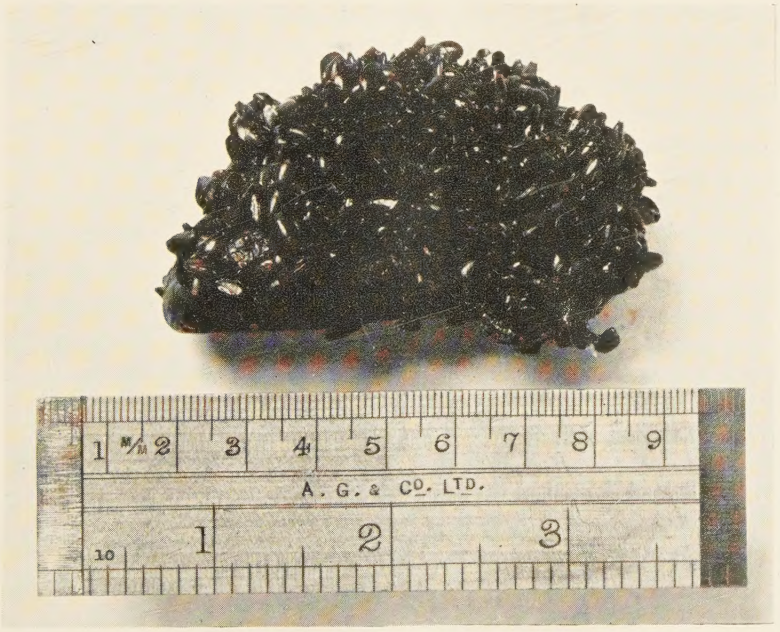


Fig. 2. $2\frac{1}{2}$*-inch mussel covered with 3-months-old spat.*

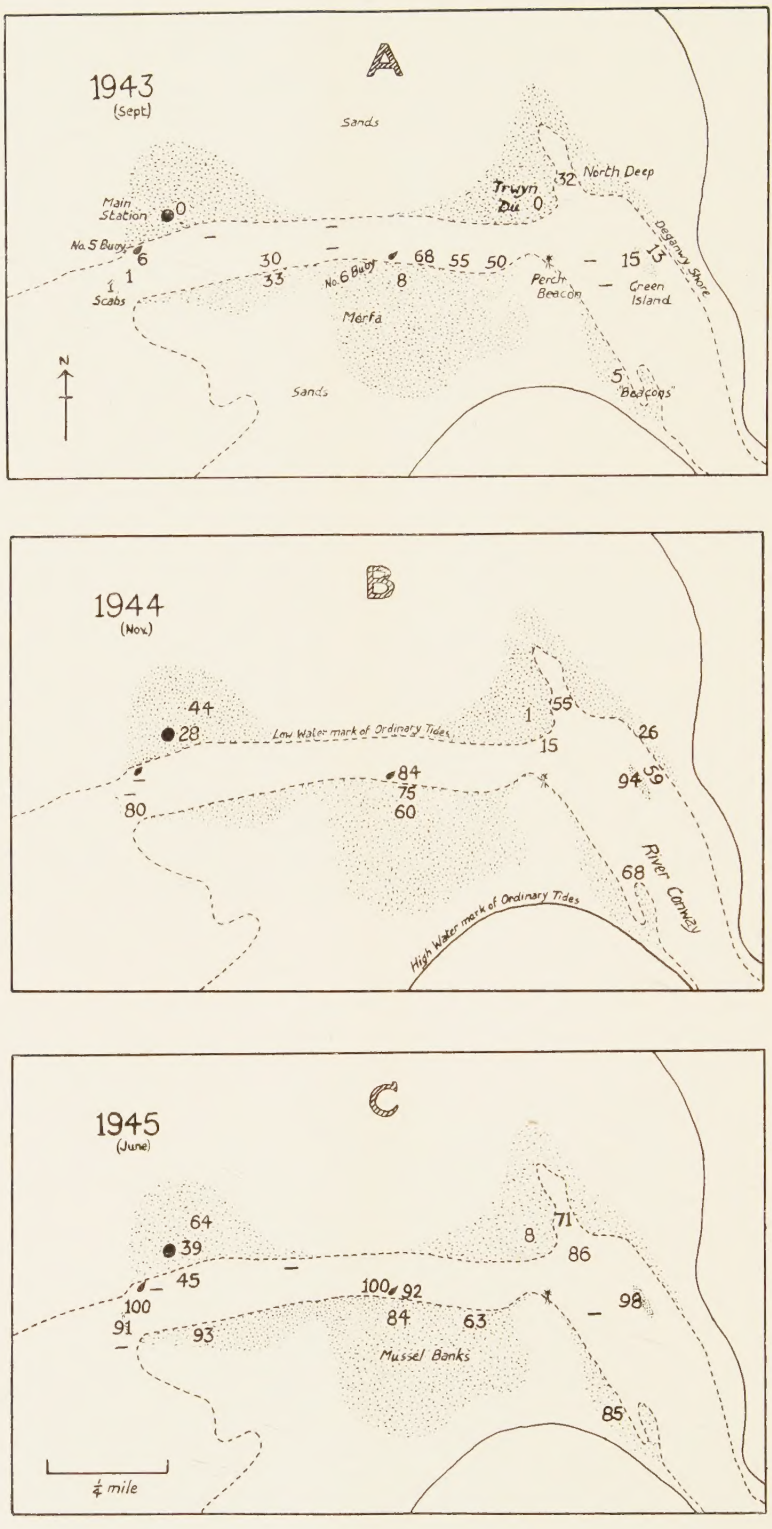
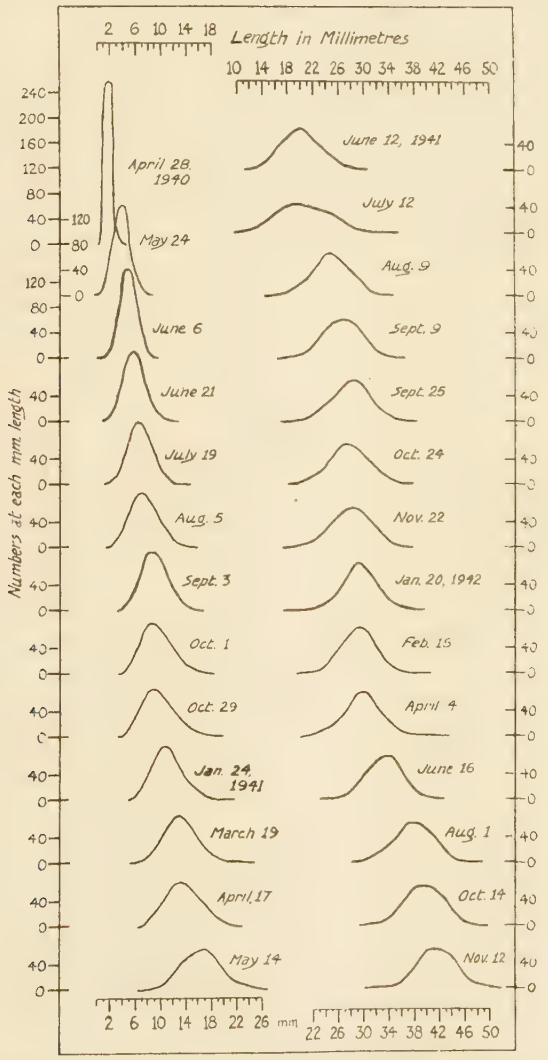


Fig. 3. *The river Conway Estuary showing percentages of mussels of* $2\frac{1}{4}$ *inches or more in length in* (*A*) 1943, (*B*) 1944, *and* (*C*) 1945, *when mussels were* $3\frac{1}{2}$, $4\frac{1}{2}$, *and* $5\frac{1}{2}$ *years old. The whole area was covered with spat in April*, 1940. *Stippled areas = approx. extent of mussel beds* — = *Blank hauls.*

II. GROWTH OF MUSSELS, 1940-1942

VEYS were made at low water of alternate spring tides (i.e. at intervals of about a th) from May, 1940, until November, 1942, and samples of mussels were collected for nination. A station was selected on a bank, near low water mark, about 100 yards east lo. 5 Buoy (since re-sited as No. 6). A small inlet enabled the position to be fixed rately on most tides. The bank in this area was at the time said by fishermen to be a l collecting ground. Each sample, consisting of a number of small clusters of spat, was cted from different parts of an area of about 20 to 30 square yards, and put into a small in which it became well mixed before a sub-sample of 500 was later taken out and sured.

Later, when it was observed that growth in different parts of the estuary varied considerably, samples were also taken from several other parts and measured. When it was



4. *Length frequency curves for samples of young mussels from regular station on bank near No. 5 Buoy from April*, 1940 *to November*, 1942. (*Samples* 500 *each*).

convenient for a mussel fisherman to join the survey, samples were also raked from t channel where the mussels were never uncovered.

Table I: *Length and weight of young mussels spawned in Spring* 1940

Date	Mean Length	Dry weight per 1,000 mussels		
		Shells and Flesh	Flesh	Shells
1940:	mm.	g.	g.	g.
April 28	2·07	0·72		
May 24	4·26	3·51		
June 6	5·39	7·53		
June 21	6·13	11·57		
July 19	7·36	16·87		
August 5	7·84	18·30		
September 3	8·56	29·88		
October 1	9·93	39·75		
October 29	10·14	49·00		
1941:				
January 24	11·66	62·56	5·06	57·50
March 19	13·72	91·50	7·96	83·54
April 17	15·00	106·96	15·51	91·45
May 14	16·98	195·28	24·28	171·00
June 12	20·73	359·32	47·60	311·72
July 12	23·12	520·26	74·06	446·20
August 9	25·41	838·46	92·66	745·80
September 9	27·13	1005·94	101·64	904·30
October 24	28·40	1164·84	94·18	1070·66
November 22	28·58	1151·30	81·08	1070·22
1942:				
January 20	29·13	1340·62	66·74	1273·88
February 19	29·68	1290·35	69·29	1221·06
April 4	30·41	1368·32	89·84	1278·48
June 16	33·76	2141·56	291·42	1850·14
August 1	38·43	3030·24	389·48	2640·76
October 14	40·09	3674·76	315·00	3359·76
November 12	42·00			

1. Main Station near No. 5 Buoy

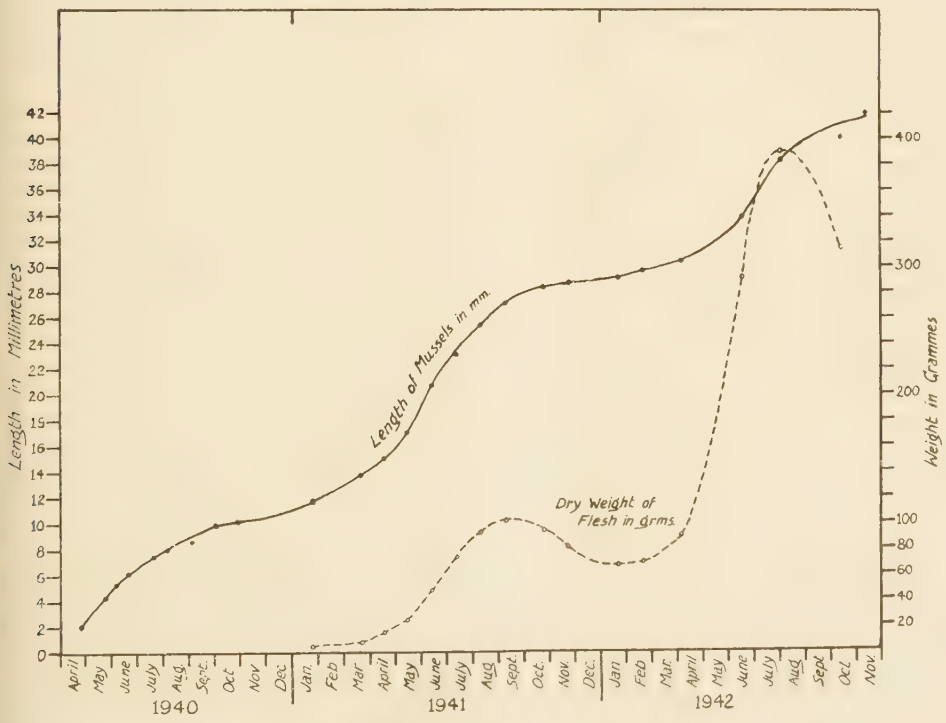
Growth in Length

Length frequency curves for all the samples from the main station from April, 1940, l November, 1942, are shown in Fig. 4. They show a steady increase in length through- the period, with a gradual flattening of the curve as the range in length increased. only irregular curve is the one for July, 1941, which indicates a sampling error. (The was not a good one, and the small inlet by which the station was marked may not have n exposed at low water).

The regularity of the curves suggests that all the mussels concerned were from the one spawning in Spring, 1940. Had there been later spawnings in 1940 they would have vn as bulges on the left of the curve or as separate peaks, but it can be seen that there none. There are a few slight irregularities to the right of some of the curves which can no bt be accounted for by differential growth, e.g. mussels in depressions in a bank being ered with water a little longer than others, and thus having longer to feed.

The mean length of each sample is given in the second column of Table I, and has been ted in Fig. 5. As would be expected the resulting curve shows that growth was rous during the Summer months and slow in Winter. This is well seen in Fig. 6, in ch the monthly increments in length are shown as histograms—see also Table II. wth was slow during the first year, but speeded up in the second. May and June were best growing months during the first two years, but in the third year growth in length eared to be retarded until June and the biggest increase took place during July.

There were no signs of any spawnings during 1941 and 1942 in any of the samples, and e was observed during the surveys of the beds, which was not very surprising as nearly he old mussels had died, but see below (p. 15) for evidence of small settlements on 6 Buoy and on the keel of the motor boat 'Mytilus II' during 1941.



5. *Curves showing growth in length of mussels from regular station near No.* 5 *Buoy, and ken line) dry weight of mussel flesh per* 1,000 *mussels during second and third year.*

Table II: *Monthly growth increments in young mussels*
(Readings from Growth Curve in Fig. 5)

	1940		1941		1942	
	Length	Increment	Length	Increment	Length	Increment
	mm.	mm.	mm.	mm.	mm.	mm.
January			11·9	0·9	29·3	0·2
February			13·0	1·1	29·7	0·4
March			14·2	1·2	30·3	0·6
April	2·5		15·8	1·6	31·3	1·0
May	4·8	2·3	19·2	3·4	32·6	1·3
June	6·5	1·7	22·5	3·3	35·2	2·6
July	7·9	1·4	24·8	2·3	38·3	3·1
August	9·0	1·1	26·7	1·9	39·8	1·5
September	9·8	0·8	27·8	1·1	40·8	1·0
October	10·2	0·4	28·4	0·6	41·4	0·6
November	10·5	0·3	28·8	0·4	41·8	0·4
December	11·0	0·5	29·1	0·3		

Fig. 6. *Monthly increments of growth in length of young mussels.*

(B) *Increase in Weight*

In an effort to get a general idea of the increase in weight, samples of young muss were partially dried in an incubator at 37°C. until a constant weight was obtained—usua in 48 hours. During the first year, when the mussels were too small to allow separation shells from the flesh, the total weight of both shells and flesh was assessed. In the seco and third years one shell valve was removed from each mussel, dried and weighed. T

r valves, containing the bodies of the mussels, were also dried and weighed. The second valves were later weighed separately after removing all traces of dried flesh. These rvations gave a general picture of the changes in both flesh weight and shell weight ng the second and third years' growth. The results are given in Table I, and shown as es in Figs. 5 and 7.

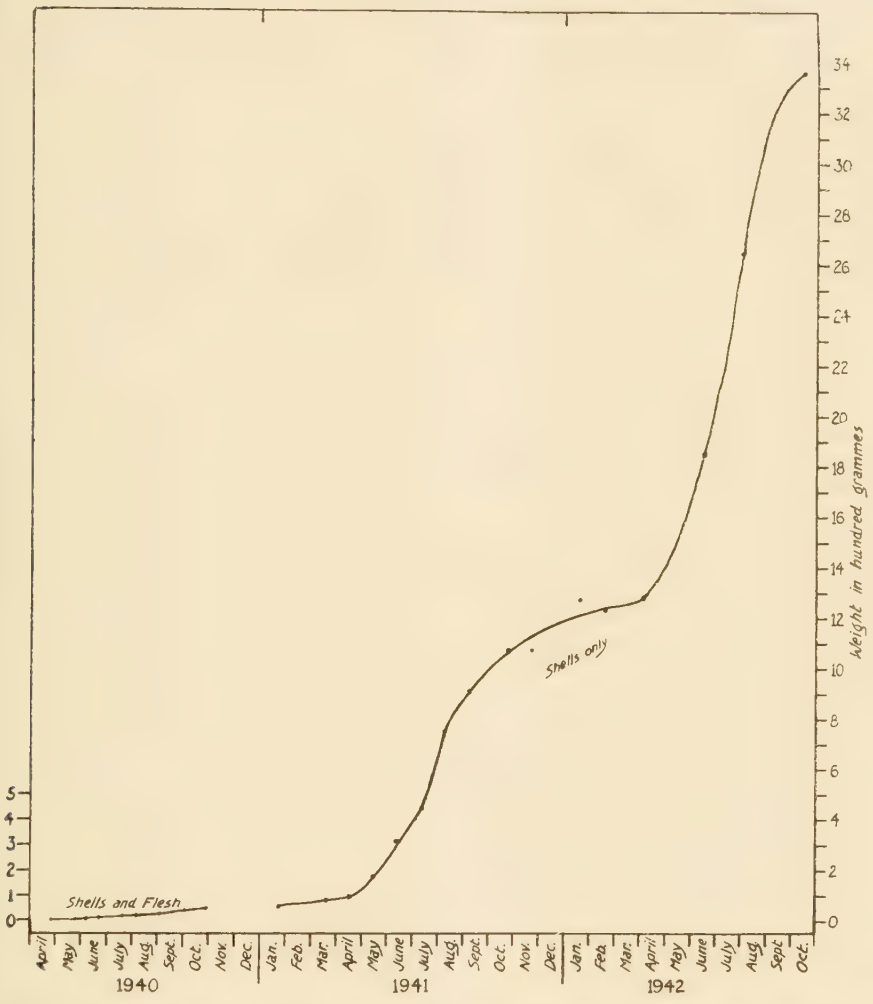

Shells and Flesh
Shells only
Weight in hundred grammes
April May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. April May June July Aug. Sept. Oct. Nov. Dec. Jan. Feb. Mar. April May June July Aug. Sept. Oct.
1940
1941
1942

Fig. 7. *Mean weight of shells (per 1,000 mussels) during second and third year, and of shells and flesh during first year.*

The curve of flesh weight (Fig. 5), shows that after brisk growth in Summer, there is a uite decrease during the Winter. This may be due to some of the fat accumulated ng the Summer being used up during the Winter months when food was in minimum tity and ciliary activity sluggish. Daniel (1924), however, in his experiments on the ration of mussels, states "the fact that in spite of physiological distress the starved sels did not draw upon the fats and glycogen in the tissue, is due in part to the intricate these substances play in the building up of the sperm and ova during the annual oductive cycle, and suggest that the mussel is unable to draw upon these reserves for ordinary activities of its body, other than reproduction."

Chipperfield (1953) using Daniel's figures for the glycogen and fat content of *Mytilus* mpare with the index of gonad development in his Liverpool material for 1946-47, d that whilst gonad development was stationary from December to March, the glycogen ent declined markedly, suggesting that some was used in the ordinary metabolic esses when food was scarce.

The shells continued to increase in weight throughout the year, but naturally at a mu slower rate in Winter (Fig. 7). The sharp increase in Summer, compared with the incre in length (Fig. 5), is due to growth in thickness of the shell. This increase was very mark during the third Summer. Increase in shell weight in Winter, when food is scarce, is r unusual in lamellibranchs, but is perhaps more remarkable when the flesh weight decreasing. Fretter (1953) states, with regard to marine lamellibranchs, that the growth the calcareous shell continues during periods of starvation and since there is little stora of calcium in the tissues it points to the uptake of salts direct from the water. She conduct

Table III: *Dry weight increments—per* 1,000 *mussels*
(Read from curves in Figs. 5 and 7)

A. Mussel Flesh

	1941		1942	
	Dry Weight	Increment	Dry Weight	Increment
	g.	g.	g.	g.
January	5·1	—	67	0
February	6·2	1·1	72	5
March	10·7	4·5	86	14
April	18·9	8·2	138	52
May	38	19·1	228	90
June	62	24	350	122
July	88	26	390	40
August	101	21	369	— 21
September	100	— 1	320	— 49
October	92	— 8		
November	77	— 15		
December	67	— 10		

B. Mussel Shells

January	60	—	1215	35
February	72	12	1245	30
March	85	13	1275	30
April	120	35	1400	125
May	235	115	1670	270
June	385	150	2070	400
July	650	275	2610	540
August	870	220	3120	510
September	990	120	3320	200
October	1080	90		
November	1140	60		
December	1180	40		

riments with mussels kept in filtered sea water, using the tracer element radioactive ntium, and showed that after two hours the strontium ions were present in the lumen e gut, in the digestive glands, and in the tissues of the gill filaments. She concludes: trontium enters so readily the tissues of the gills, and more especially the gut, there is no on for believing that the divalent ions of calcium would not follow a similar course so provide for the continuous growth of the shell even in starved individuals." Our ts support her conclusion. It is conceivable that the loss in flesh weight may be due rt to this building up of the shell.

Monthly weight increments read from the curves in Figs. 5 and 7 are given in Table III. se for shell growth are shown as histograms in Fig. 8. They show similar features in years: the greatest increase in weight taking place during July and August. They r somewhat from the length increments shown in Fig. 6, especially during the second . The greatest increase in length was in May and June, while that for weight was in and August. In the third year the difference was less marked, July being the best th for both length and weight, but the second best month was June for growth in th and August for increase in weight.

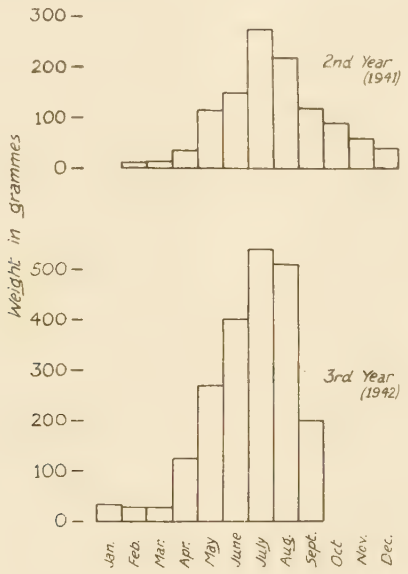


Fig. 8. *Monthly weight increments of mussel shells (per* 1,000 *mussels).*

2. Growth Variations in Mussels in other parts of the Estuary

such a dense and extensive population of mussels, growth was bound to be slow to vary greatly according to the position occupied by the mussels. The speed of growth nded upon the length of time the mussels were covered by seawater and thus able to Those in the channel, being immersed all the time, could feed continuously and so more quickly than those which were exposed at low water. Growth was almost as good ose mussels living on the small banks in the channel—'The Scabs' and on 'Green d' where they were only exposed for a very short time at low water of good spring .

Growth on the banks was slower and more varied. The best growth took place near water mark, especially on the southern side of the estuary (The Morfa) and particularly ose mussels which inhabited the strip of ground between low water of neap and spring . The poorest growth took place on the higher parts of the banks where the mussels exposed for several hours each tide, especially on the extensive Morfa beds where

they grew very slowly indeed, became stunted and were in poor condition. The greater pa of our samples was taken within 40 or 50 yards of low water mark of spring tides. Of tl stations most frequently sampled, the smallest mussels came from the bank on the weste side of the North Deep (Trwyn Du), and from just above low water mark on the easte shore of the estuary where the river takes a sharp bend. At both these places the ba slopes comparatively steeply and the mussels within a few yards of low water are marked smaller than those near the low water line. The station slightly farther up river at 'T Beacons' gave mussels which varied from much bigger than the average to rather small As mentioned above, the population here fluctuated a good deal.

Mussels from the North Deep were intermediate between banks mussels and tho from the channel. At low water of springs most of them were exposed, and the others we in very shallow water so that they could always be collected by hand. They varied great in length; some months they were up to 10% longer than the standard, i.e. the musse at the station near No. 5 Buoy, and at others as much as 10% shorter.

After analysing all our results it appeared that the main station on the bank near No. Buoy (shown as a black dot on the maps in Fig. 3), was well chosen, as growth there w about average for the banks in the regions within about 40 or 50 yards of low water mar

III. LATER GROWTH

Regular sampling ceased in November, 1942, as the Ministry's motor vessel 'Mytilus had been put at the disposal of the Naval Authorities. Mussel fishing had ceased after big spatfall of 1940 so that no mussel boats were going down the estuary, and help could be obtained from that source. Further, a military training camp had been established on south bank of the estuary on the Morfa, and firing practice at targets on the mussel b was taking place regularly at low-water, i.e. at the time when we should need to co samples. For some time it had been necessary to make arrangements with the mili authorities to suspend firing practice while we were collecting samples—usually in the e morning before practice was due to start—and on at least one occasion they forgot an received frantic signals to leave the area.

At the end of 1942 when the mussels from the spawning of Spring, 1940, were $2\frac{1}{2}$ y old, their mean length was only 42 mm. on the banks exposed at low water, and ab 46 mm. in the channel where the mussels were never uncovered. Less than 1% and respectively were over 2 inches in length—i.e. the minimum size at which they co legally be taken from the fishery for marketing.

1943

On the 3rd September, 1943, we secured the use of the Ministry's motor boat for visit to the mussel beds, and made the necessary arrangements with the military authoriti for a temporary suspension of firing practice over the beds, and made an extensive surve Twenty-one stations (see Fig. 3A) were sampled on the banks and in the channel (a musse man assisting in the latter).

The mean length of the banks mussels was now about 50 mm., and of those in tl channel about 54 mm. The percentage above the minimum marketable size of 2 inches length varied from 1 to 96. Two inches is rather small for Conway mussels, so in order present a better appreciation of the state of the fishery in relation to marketing, t percentage of those of $2\frac{1}{4}$ inches and over was calculated, and these figures have be used on the maps in Fig. 3.

From Fig. 3A it will be seen that on the north side of the estuary, and on the adjace banks, there were no large mussels except in the North Deep to the west. Two of th channel stations on the north side produced several blank hauls. Most of the large musse were found on the south side of the channel, especially on a narrow bed on the slop

veen No. 6 Buoy and the Perch Beacon. The mean percentage of mussels of $2\frac{1}{4}$ inches over was 20 (= 9% on the banks and 29% in the channel). This was not considered icient to warrant any attempt to re-open the fishery, even if arrangements could have n made with the military authorities.

The mussels at this time were $3\frac{1}{2}$ years old and with normal growth would have reached rketable size, excepting those high up on the banks. Growth was therefore somewhat ppointing. Although there had been considerable scouring on the banks the beds e still very densely populated. The most surprising and disappointing feature of the vey was the paucity of mussels in the channels in regions where musselmen usually had d hauls.

1944

urvey was made on the 4th November, 1944 (see map, Fig. 3B). The mean length he mussels was then 56 mm. on the banks and 60 mm. in the channel. The percentage inches and over was 88 (= 68% on the banks and 95% in the channel), and for those $2\frac{1}{4}$ inches and over the mean was 52% (= 14% on the banks and 65% in the channel). s was an appreciable increase on the previous year, but still rather poor considering the mussels were now over $4\frac{1}{2}$ years old.

The southern side of the channel and the adjacent banks near the low water mark again wed the highest percentages, only being exceeded on the capricious Green Island with % of $2\frac{1}{4}$ inches and over (Fig. 3B).

All the stations on the eastern side of the estuary showed a great improvement on 1943. e main station near No. 5 Buoy now had 28% as against none the previous year, and newhat surprisingly there were 44% at a station some 30 yards farther along the bank. The fishery was now fairly satisfactorily stocked with large mussels, but it was not acticable to re-open it.

1945

e next survey was made on the 13th June, 1945, to assess the prospects for the owing winter season. The war was drawing to a close, but the military training camp still very active, and arrangements had again to be made for firing practice to be pended while the survey took place.

The mean length of the mussels had increased to 60 mm. on the banks and 65 mm. he channel, and over 90% were 2 inches or more in length. Fig. 3c shows that the centage of those of $2\frac{1}{4}$ inches and over had increased throughout the fishery. The mean

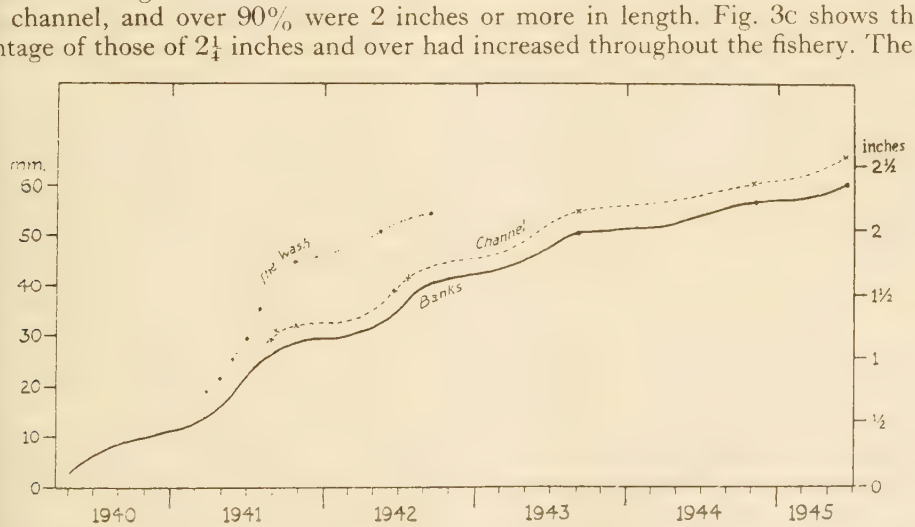


Fig. 9. *Curves showing growth in length during $5\frac{1}{2}$ years of Conway mussels from regular stations on Banks (continuous line) in Channel (broken line); and of mussels from The Wash (dotted line).*

percentage over the whole fishery was now 75 (= 72% on the banks, and 83% in th channel). There were four stations in the channel where blank hauls were registered b the others showed a comparative abundance; in the region of the Scabs banks in particul there was a marked improvement on previous years. Of the banks near low water ma those on the south side were again the best.

The banks generally were well stocked with large mussels now 5½ years old, and althoug the channel was bare in parts and not as richly stocked as had been hoped, there were sig of improvement. The prospects for a successful fishery during the winter were fairly goo

To complete the picture of the growth of the mussels during the five years since th were spawned in 1940, a growth curve is shown in Fig. 9, which includes the results fro the surveys of 1943, 1944 and 1945. The mean lengths of the mussels in all the rak samples—from the channel—from 1941 onwards are shown by crosses, connected by broken line.

IV. THE 1940 SPATFALL IN THE WASH

Heavy falls of mussel spat in the Spring of 1940 were reported from the Wash. This d not come to our notice until February, 1941, so that we have no records of growth length during the first year. Through the courtesy of the Eastern Sea Fisheries Committe samples of young mussels from this spawning were collected for us during 1941 and 194 Their Chief Fishery Officer reported that most of the spat fell clear of the mussel bed and he estimated that it covered an area of about 4 square miles. Sampling began March, 1941, and continued until September, 1942, as follows:

	Mean length mm.	
24th March, 1941 ..	19·1 ..	
24th April, 1941	21·4 ..	
26th May, 1941	25·3 ..	
26th June, 1941	29·3 ..	
29th July, 1941	35·4 ..	
20th October, 1941 ..	44·9 ..	5% were 2 inches and over
12th May, 1942	50·5 ..	42% were 2 inches and over
10th September, 1942 ..	54·1 ..	83% were 2 inches and over

The mean lengths are plotted on Fig. 9, for comparison with Conway mussels. As w be seen growth was much quicker in the Wash mussels. The mean length in Septembe 1942, when they were 2½ years old was equal to that for 4-year-old Conway bank musse and for 3-year-old channel mussels. The percentage of those of minimum marketable siz was then 83 compared with only 1 to 2% at Conway.

V. COMPARISON WITH GROWTH IN OTHER LOCALITIES

Most observations on the growth in length of mussels appear to have been based on fe measurements, and indeed some are clearly casual approximations. There are a number difficulties which prevent anything but an approximation from being made. We have see how variable growth can be in the comparatively small area of the Conway River Estuar when dealing with the crop of mussels from a single spawning. When, as frequently happen successive spawnings occur over several months, there would be even more variation; an of course living conditions vary in different localities.

Table IV: *Total length of mussels at end of each year, recorded by various writers*

Age in years:		1	2	3	4	5
		mm.	mm.	mm.	mm.	mm.
Wales: (This report)	Banks	11 (15)	29 (31)	42 (44)	51 (52)	57 (58)
	Channel	12 (17)	33 (35)	46 (48)	55 (57)	61 (63)
Canada: (Mossop)	St. Andrews	11	24	34	42	
New Brunswick	Niger Reef	11	27	42	54	63
Nova Scotia: (Mossop)	Digby	16	34	50		
England: (This report)	The Wash	19	49	54 +		
France: (Herdman):	Bay of Auguillon	19*	38*			
Scotland: (Ritchie):	Firth of Forth	27 (32)	40 +			
Holland: (Havinga):	S.G. 1020	34	57	72		
	S.G. 1017	28	43	49		
	S.G. 1015	25	36	39		

*approx.

In Table IV are set out growth measurements recorded by other workers, along with se for Conway and the Wash. The figures for Conway give the lengths up to the end of cember in each year as read from the curves in Figs. 5 and 7. The length at the end of a year is shown alongside in brackets. The Dutch figures are also for the period to the of December.

At Conway we were able to follow month by month the growth of mussels from one spawning, but as the beds were so overcrowded especially during the first year, the ults cannot be regarded as normal. Dodgson (1922) gave the length of mussels of the vious year's spawning at Conway as $\frac{3}{4}$ inch (19 mm.) on 29th May. The length of the 0 year class was the same –19·2 mm. –at the end of May, 1941 (Table II); this length mainly due to the large growth increment for May, 1941 (Fig. 6), which may have ught the length to near the average but which also shows how difficult it is to fix an rage for growth in any area. We have no British measurements with which to compare growth of Conway mussels other than those given above for the Wash (Table IV). owth there was much better than at Conway being 19 mm. for the first year as against 12 mm., and 30 mm. in the second compared with 18-21 mm. at Conway. Both areas eed in showing the quickest growth in the second year. It is very probable that Conway ssels generally take 4 to 5 years to reach marketable size when left on the crowded beds. aying and cultivation on less crowded grounds would speed up growth, and it should possible to get them to marketable size in 3 years.

Field (1921-22) says that under ideal conditions a mussel will increase in length about ch annually for two or three years, but that such conditions are very rarely found, and the average rate of growth on natural beds is much less; he also says that ordinarily kes 5 to 7 years to reach a length of 3 inches.

Mossop (1922) bases her estimates of growth in length in Canadian mussels on check ks on shells of 2 years of age or over. Her results are surprisingly similar to those for way.

Havinga (1929) in his careful work on Zuiderzee mussels from areas of different salinities G. 1015, 1017 and 1020), found that growth was poorest in water of the lowest salinity, best in that of the highest. Growth was rapid during the first year, exceeding 1 inch ll three areas, i.e. over twice as much as at Conway. As the mussels were spawned in nmer they had only a short growing season before the Winter, when as at Conway, e was a check; the growth therefore was very rapid indeed. Growth slowed down during second and third years, especially where the salinity was lowest, and only in those in

the water of highest salinity did it exceed that of Conway mussels for the same perioc There was a secondary check in growth about June in the second and third years, du Havinga thinks, to sexual activity.

Orton (1914) stated that mussels at Plymouth grew 35 mm. to 40 mm. ($1\frac{1}{4}$-$1\frac{1}{2}$ inches between April and November in their first year, which seems exceptional growth.

Wright (1917) gives $\frac{1}{4}$-inch to $\frac{1}{2}$-inch as the length of mussels in Cardigan Bay, afte 15 months.

There are a number of references to growth of mussels on fixed objects; Fischer (192 tells of finding mussels 54 mm. long in a bathing pool in April, 1928, nine months after th pool had been built. He also refers to an observation of Dautzenberg and Durouchou (1913) who found mussels of 50 mm. in June, 1897, on the keel of a boat (scraped i August, 1896), in a floating dock at Saint-Servan, i.e. 10 months after. Ritchie(1927)studie the growth of mussels on an experimental buoy anchored on 11th May, 1920, at Portobell in the Firth of Forth. Growth conditions were considered to be favourable because of th large amount of organic matter discharged from the many sewers in the neighbourhoo and the consequent abundance of food organisms in the water. He found that growth wa very rapid during the Summer; in October, five months after the buoy was moored, th spat which had settled on it had an average length of about 1 inch (24 mm.), and by Augus of the following year, i.e. after 15 months, they averaged 40 mm., while some specimen were just over 2 inches in length (54 mm.). It is interesting to note that growth did not slo down very much in Winter as the average length increased by 8 mm. between 23rd Octobe and 20th April. Field found that young mussels grew to $\frac{3}{4}$ inch between April and Augus on ropes on fish traps.

VI. SPATFALL IN 1941

LITTLE evidence was found of other spawnings on the mussel beds during the period our monthly surveys, which was not very surprising as the old mussels were rapidly dyi from starvation; however, some young mussels spawned in 1941 were found on the ke of our motor boat and on the underside of No. 6 Buoy, and are here recorded as th demonstrate the occurrence of several different spawnings in that year. The preferenti

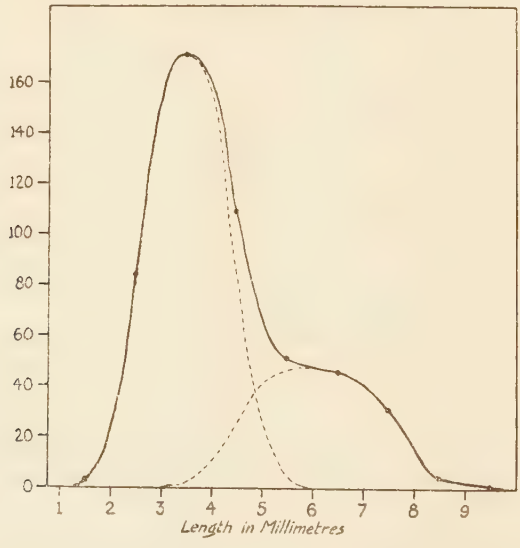


Fig. 10. *Mussels from keel of M.V.* 'Mytilus II' *collected on 20th August,* 1941, *showing indications of two spawnings.*

lement of mussels on floating structures is well known, but has not previously been orded, as far as is known.

1. Keel of Motor Vessel 'Mytilus II'

en the Ministry's motor vessel was scraped on the 20th August, 1941, large numbers oung mussels were found attached to the keel. A sample of 828 was measured. The ge in length of the mussels was from 1 to 9 mm., the mean length being 4·3 mm. all as was the range it was clear that they were from two separate spawnings. The main k was at 3·5 mm., but there was a pronounced bulge on the right of the curve (see . 10), indicating another peak at about 6 mm. The spawnings are calculated to have en place in June and May respectively.

As the 'Mytilus' was moored above Conway Bridge and at that time only made asional trips of a few hours duration down the estuary, the comparatively small ulation of large mussels living in that part of the river may have been responsible for spawnings. The big 1940 spatfall did not extend so far up the river, consequently the e mussels there had not been smothered and had survived.

2. No. 6 Buoy

the 22nd November, 1941, No. 6 Buoy (now re-sited as No. 7), was found to be ered below the water line with young mussels. A sample was removed and 500 measured. e mean length was 7·8 mm., and the range was 3 to 15 mm. When the figures were tted the resulting curve showed two equal peaks at 5·5 and 8·5 mm. A second sample s taken on the 20th January, 1942, and this showed peaks at the same lengths, but that 5·5 mm. was a little higher than the other. The mean length was a little less than in vember—7·6 mm., and the range 2 to 14 mm. The next sample was collected on the h February when the mean length had increased to 8·6 mm. with a range of 2 to 17 mm. e main peak was about 9 mm. and the secondary one at about 6·5 mm.

No further samples could be obtained as on the next visit, on the 4th April, we found t the buoy had been scraped and re-painted. This buoy was always afloat except for a y short time at low water of extreme spring tides, so that feeding conditions would be ter than for the mussels on the beds. Growth must have been quicker than on the rcrowded beds. It has therefore been calculated that the spatfalls corresponding to the peaks took place in June and August.

We see then that there was evidence of three spawnings during 1941—in May, June l August—but that none of them was large enough to be noticeable on the beds.

VII. GROWTH OF 1940 SPAT IN CONWAY TANKS

me of the spat from the big spawning was kept in a metal sieve in one of the concrete ks at the Conway Purification Station. The water in the tank was changed nearly every during the mussel season (Sept.-April), but only occasionally during the Summer.

Growth was very rapid at first and by the end of 1940 the mussels were 55% longer n those on the mussel beds in the estuary. At the end of 1941 they were 34% longer, but r growth slowed down rapidly so that by the end of 1942 they were only 1% longer. e experiment was abandoned in May, 1943 when the mean length was a little less than se on the beds. The mortality during these three years was negligible. Average water mperature in the tanks would be somewhat above that of the estuary.

VIII. SPAWNING PERIODS

servations on the spawning periods of the sea-mussel (*Mytilus edulis L.*) are some- at scattered and frequently indefinite. Perhaps the most definite are those concerning

the great French mussel fishery in the Bay of Aiguillon, and of Chipperfield (1953) fro several localities in Britain.

Herdman (1893) and Lambert (1950) both say that spawning takes place in the Bay Aiguillon in early Spring. Berner (1935) puts it more definitely as occurring in Februa and March, and never later than the first fortnight in April, depending upon when t severe weather of Winter ends and the temperature of the water rises. That spawning tak place earlier here at what is about the southern limit of this northern species, than in Briti waters, is no doubt due to the earlier warming up of the sea. It is also possible that t higher temperatures in Summer are inimical to subsequent spawning.

In Holland, Havinga (1929) says that spawning in the Zuiderzee is in Summer, a Lambert (1935) gives the main spawning period in Zeeland as June, but says that it begi there in March and that there are other small liberations during May and July. Baggerm (1953) found that in the Waddensea *Mytilus edulis* settled from mid-May to mid-Augu with the greatest numbers from mid-June to mid-July. Berner says that on the coasts Holland spawning takes place in March and April and not later than the first fortnight May.

In the Sound between Denmark and Sweden, Jørgensen (1946) found veligers quantity from May to October inclusive, but smaller numbers occurred until January, a a few were present in early Spring. In the Isefjord, however, spawning was very rapid completed between late May and mid-July.

Chipperfield (1953) recorded the time of spawning during 1946 and 1947 at a number places on the British coast, including Conway, Brancaster, Liverpool, Brixham and Portre Five stages of gonad development were recognised, viz., neuter or resting spent; onset gametogenesis; follicles well developed but unripe; ova and sperm ripe; and follic empty. In Table VIII (p. 459) Chipperfield gives a summary of his findings; in all localit with one exception, spawning began in May, and was completed towards the end of t month or in early June. In the exceptional case spawning began in the last week in Ap His observations on Conway mussels were made in 1947 only; this year was peculiar in th there was very severe frost in January, February and early March. In many way resembled 1940 but there were some important differences. Spawning at Conway in 1 occupied 9 days only, a period whose brevity was equalled only by mussels held in a p at Brancaster. In the other localities from which mussels were examined in 1947 spawn occupied 16-27 days. In years other than 1947 the observed spawning period varied fr 18-51 days. He says that he found no evidence of periodic spawning or of more than discrete spawning period in any locality during the 4 years of investigation.

Ritchie (1927), working at Portobello in the Firth of Forth, found that the season heaviest spatfall extended from late April throughout June and July until August, but th if conditions were favourable it might fall as early as February, and in favourable conditio might continue into the Autumn months.

In a booklet published by the Marine Corrosion Sub-Committee of the Iron and Ste Institute (1944) the period of settlement of mussels round the coasts of Great Britain based on regular observations during 1941-42 at two stations at Caernarvon and Millpo —is shown in their Fig. 1, as from July to October, the heaviest settlements being i September and October. It is understood that this is the normal period of settlement Millport. In the Menai Straits, opposite Caernarvon,the season of attachment of sedentar organisms, including mussel spat, was observed by Cole (unpublished) in the years 194 1949. Mussels settled in practically every month of the year but were most frequent i March, April, July and August. The settlement of *Tubularia larynx* did not begin unt June, but certain hydroids, particularly *Gonothyraea loveni* settled in early Spring. Th possible importance of such hydroids in facilitating attaching of young mussels is mentione by Korringa (1951).

Pyefinch and Downing (1949) say that settlement of mussels at Millport usually occurre at the time when *Tubularia larynx* was settling in abundance which was usually about Jul

McIntosh (1891) gave the spawning season off the English north-east coast as Marc to June, but described settlements on zoophytes in July and August which suggested late

nings. He gave a similar spawning period for mussels in St. Andrew's Bay, but from description of heavy settlements on ropes, buoys and floating barrels of the salmon nets in August, it would seem that there was an important Summer spawning there

Lebour (1906) found spawning to take place off the Northumberland coast from May

Locality	Authority	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Remarks
FRANCE											
Bay of Aiguillon	Herdman (1893)	Early	Spring								
Bay of Aiguillon	Berner (1935)	+ +	+ + +								
Bay of Aiguillon	Lambert (1950)	Early	Spring	+							
HOLLAND											
Coasts	Berner (1935)		+ +	+ +	+						
Zuiderzee	Havinga (1929)				Summer						
Zeeland	Lambert (1935)		+		+ +	+ + +	+ + +				
Waddenzee	Baggerman (1953)				+ +	+ +	+ +				
DENMARK											
The Sound	Jorgensen (1946)				+ +	+ + +	+ +	+		+	Great variation.
Isefjord	Jorgensen (1946)				+ +	+ + +	+ +	+ +	+		
SCOTLAND											
Isle of Skye	Chipperfield (1953)				+ +	+ +	+ +	+			
Firth of Forth	Ritchie (1927)			+	+ +	+ +	+ +		+		
Millport	Pyefinch (1950)				+	+ +	+ +	+	+ +	+ +	
Millport	Iron & Steel Inst. (1944)					+	+	+			
ENGLAND											
N.E. Coast	McIntosh (1891)		+	+ +	+						
Northumberland	Lebour (1906)			+	+ +	+ +	+ +	+ +	+		Period same as Scotland. Also Spring spawning (Mitchell).
East Coast	Harding (1884)		+	+ +	+	+	+				
The Wash	This Report			+ +	+	+					
Brancaster	Chipperfield (1953)			+	+	+ +					
Lancashire Coast	Johnstone (1899)				+	+	+	+			Much variation.
Liverpool	Chipperfield (1953)			+	+	+	+				
Plymouth	Lebour (1938)			+ +	+	+ +		+			
Plymouth	Chipperfield (1953)				+ +	+ +	+				
Brixham	Chipperfield (1953)			+	+ +	+		+			
Exe Estuary	Allen & Todd (1902)				+		+				
General	White (1937)					Summer	+	+			Considerable local differences.
WALES											
Conway	This Report			+ +	+	+		+			
Caernarvon	Chipperfield (1953)			+	+ +	+	+		+	+	
	Iron & Steel Inst. (1944)							+	+	+	
Cardigan Bay	Cole (unpublished)			+ +			+	+			Some settlement most months.
	Wright (1917)			+	+ +		+	+			
U.S.A.											
Atlantic Coast	Field (1922)			+	+	+	+	+	+		

until August or even September, with the greatest spatfall towards the end of the Summe She quotes a Mr. Mitchell as saying that there were two spawnings—one in Spring an another about August.

Harding (1884) said that in British east coast waters spatting usually took place in th Spring, and that spat could be found until the beginning of June.

Johnstone (1899) stated that maximum spawning on the Lancashire coast was in Jul and that there was a secondary one earlier in the year, but that there was much variation.

White (1937) in her monograph on *Mytilus edulis* says that spawning in English wate takes place in Spring, with a second and possibly more important occurrence later in th Summer. She states that at Plymouth spawning has occurred in January, February an March, and that spent mussels have been taken in May and August.

At Plymouth, Lebour (1938) states that "the chief breeding season is from April t June, but some may be found ripe at almost any time."

Allen and Todd (1902) found mussel spat—1 mm. in length—extremely abundant o *Enteromorpha* in the River Exe Estuary in July and August.

Wright (1917) says that in Cardigan Bay spawning probably begins at the end of Apr or during May.

Field (1921-22) says that on the Atlantic coast of the United States spawning begir in April and continues on throughout the Summer until well into September. At Wooc Hole (Mass.) Biological Station he had secured spawning individuals every week throughou the season from 20th June to 15th September.

The present observations relate only to the enormous spatfall which occurred in Apr 1940, at Conway, in North Wales, and was also recorded at many other places round th coasts, notably in The Wash, the River Dee Estuary, and the Lancashire coast fr Lytham to Morecambe Bay. At Conway in 1941 there were small spawnings in May, Jun and August. My predecessor, Dr. R. W. Dodgson, in a departmental report, dated 7th Jun 1922 (unpublished) stated "It was noticed on the 3rd March this year, that there had be a very heavy spatfall (at Conway), the sea-weed being covered with young ambulato mussels. This was of special interest as it is by far the earliest spat on authentic record."

When all these records are tabulated (Table V) it seems clear that *Mytilus edulis* spaw in Spring in most areas even if this is not the principal spawning of the year as it was Britain in 1940 and 1947, and that, except perhaps on the French coast, there may be sor spawning in any month from March until the end of the Summer.

It is constantly stressed that the onset of spawning depends upon the advent of Spri whether it is early or late. Berner believes that the factor of greatest importance is a sudd *fall* of air temperature of from 10° or 12°C. He remarks that musselmen know very w that sexually ripe mussels put into uncovered baskets and left overnight exposed to fro eject some of their spawn. He gives as a second factor a sudden diminution of salinity, b both factors could act together. He says that in France, *Mytilus edulis* only spawns once- in Spring.

Iwata (1952) found that spawning in *Mytilus edulis* could be induced experimentally b a sudden rise of temperature from about 7°C. to about 15°C. He also induced spawning b an injection of isotonic M/2 KCl into the visceral cavity, and by electrical stimulatio which caused mussels with immature eggs to discharge an abundance of mature egg within an hour. From his experiments it would appear that shock effects of various kind may cause spawning to take place.

Field (1921-22) also made a number of experiments in an effort to find out wha stimulated the act of spawning but with negative results:—"Ripe mussels were transferre from cold to warm water and *vice versa*; from water of high density to that of low and bac again; they were exposed to the air from one to three hours and then submerged, subjecte to swift currents and then still water, but in no case was there positive evidence that i influenced the act of spawning."

We have seen that spawning can take place all through the Spring and Summer o English and Welsh mussel beds. The enormous spatfall of Spring, 1940, would appear t have involved the entire population of mussels—certainly there was no other spawning a Conway in that year, or in the Wash. Why then did they all spawn at the same time in s

y localities ? Was there one factor common to all areas ? During January and February,), there was a quite extraordinarily severe frost all over Britain. Apart from two short 's, the severe frost extended over four weeks at Conway and mussel fishing was at a dstill. Over 20 of frost was recorded at times. The Meteorological Office (1949) records January, 1940, was the coldest month since 1895. The main period of frost was between 10th and 24th, while between the 25th and 29th there was an exceptionally severe ed frost the effect of which was most marked in southern and western England and in es. They also report that in February, 1940, the frost was the most severe since 1895.

Had this extreme cold any bearing on the phenomenal spatfall ? I think it had. The sels exposed on the banks at low water must have been greatly affected by frost, while litions in the channels must also have been extreme, particularly when ice-cold river r came down on the ebb tide. Hard conditions may induce early spawning and so ensure survival of the species. I have recorded with regard to the herring (1937): "It is curious although 1931 was such a good feeding year both off Shields and in the open sea, Hodgson's records show that in the East Anglian Autumn herring fishery of 1934, and 1936, the 1931 year class, i.e. those fish spawned after the rich feeding year of l, was a poor one, while the 1932 year class—spawned after a poor feeding season—was abundant as three-year-old fish in 1935, and was the dominant year class in 1936. s seems to be a paradoxical state of affairs—well nourished fish producing fewer geny than those that were ill nourished."

Harding (1884) stated that "On the 25th May, 1879, *after a very severe winter of about weeks' continuous frost* I found on one of the beds under my charge several acres of d mussels about the tenth of an inch in length." He further remarked that "In the ing of the year 1879 and the Spring of 1880, overwhelming quantities of brood were d on the scalps of the east coast of England, which might be measured by hundreds cres. There has not been a fall of spat since." The italics are mine.

Here we see that a similar state of affairs existed over 70 years ago; a long period of re frost followed by a heavy and extensive spatfall, and no further noticeable spatfall he years immediately afterwards. This supports our belief that the 1940 spatfall may e been a direct consequence of the severe frost stimulating all the mussels to spawn at e.

In 1947 also there were long periods of severe frost between late January and March no early mass spawning resulted. Chipperfield (1953) found that spawning did not in until May, and at Conway lasted only 9 days in all, during which over 80% of the ssels spawned. There was however no great settlement of spat and when our customary vey just prior to the next mussel season was made, no unusual quantity of young ssels was noticed.

Ursin (1954) says "According to Bahr (1949, Fishchereiwelt, *1*, 6, p. 86) the stock of ssels in the German Waddensea was considerably reduced during the severe winter of 6/47. In the summer of 1947 a heavy spatfall took place so that in 1949 the stock was nd to consist almost exclusively of the 1947 year-class. E. Smidt (1951, Medd. Danm. keri- og Havunders., Fiskeri, II, p. 87, and verbal information) has observed similar cts of this icewinter in a locality north of Esbjerg. There is much in favour of the view in 1952-53 the majority of the Danish Waddensea mussels were, also, of the 1947 r-class." It would seem from these observations that the severe frost of early 1947 was owed by large spatfalls of mussels on the North Sea coasts of Germany and Denmark ere the frost may have been more intense than in Britain.

A high survival rate of the mussel larvae derived from the mass spawning of 1940 was ured by the occurrence, immediately after the thaw, of a period of quiet sunny weather. e absence of strong winds reduced the mixing of the estuarine and outside waters to minimum so that the larvae were not dispersed widely during their pelagic phase. s believed that a large proportion were thus enabled to mature and settle in the vicinity he commercial mussel beds. It has been found (Waugh, 1952) that quiet sunny weather ours the multiplication of the minute flagellates upon which most marine larvae feed, this factor must have had an important influence on the rate of development and vival of the larvae.

A big spawning of a commercial species is usually looked upon as a fortunate circu stance, and would normally be expected to lead to a flourishing crop. It did so eventua in the Conway fishery, but the immediate effect of the glut of young mussels from the 19 spawning was disastrous. As mentioned above the old marketable mussels were smothe and deprived of their ration of food by their multitudinous offspring,and being weak fr the effects of the cold conditions and of spawning, rapidly lost condition and died. T fishery had to close down, and as the growth of the overcrowded young mussels was slo they did not reach marketable size in any quantity for five years. Had this occurred peacetime, no doubt some effort would have been made to thin out the stock to allow bet and quicker growth, but in any case the musselmen would have had a lean time.The w however, had been in progress a year when the next mussel season was due to begin, a with the young musselmen in the forces and the older men able to get other employme little hardship resulted, and so we find that a local disaster was averted by the grea disaster of war.

IX. SUMMARY

A Phenomenally heavy spatfall of mussels took place in the River Conway Estua in the Spring of 1940, when an area of about 1,000 acres of mussel beds and sands w entirely covered with the spat.

Monthly samples of mussels were collected from a selected station during the fi three years, and occasional samples from various parts of the estuary. Measurement growth in length and weight were made. A further survey was made in each of the follow three years.

Growth was most vigorous in Summer, and very slow each Winter. The dry weig of mussel flesh decreased during the Winter, but the shells continued to increase in wei

Growth in different parts of the estuary varied considerably according to the leng of time the mussels were in the water and able to feed. The best growth took place in th mussels living in the channel which were never uncovered, while the poorest growth in the mussels on the highest parts of the banks which were exposed for long period low water of each tide. The best growth on the banks occurred in the region between lo water of ordinary and spring tides.

Dispersion of the spat was slow at first due to mild quiet weather, but speeded up w the advent of rough weather in Autumn and Winter. The spat with poor anchorages w the first to go, especially those settled on the sands. By the end of the third year the ar covered with young mussels was little more than that of the old mussel beds, but they we still overpopulated.

As the young mussels grew they smothered their parents which were starved of fo and died. The fishery had to close down. Growth was slow during the first year, owing overcrowding, but improved during the second and third years. It was only after 5 yea growth that there were enough mussels of marketable size (2 inches and over) for th fishery to be re-opened.

In January and February of 1940 there was an exceptionally severe frost lasting ov a month, and it is suggested that this was the principal cause of the extraordinary spatfa by promoting mass spawning of the stock of mussels. A good survival rate of the larva was ensured by the occurrence of a period of quiet sunny weather immediately followin the thaw, when the larvae were in the pelagic phase.

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